WRP Technical Note WG-EV-2.0
April 1999

Case Study: Application of the HGM Western Kentucky Low-Gradient Riverine Guidebook to Monitoring of Wetland Development

PURPOSE: One of many potential uses of the hydrogeomorphic (HGM) approach for assessing wetland functions is the monitoring of newly restored wetland sites to determine how quickly wetland functions develop and whether function-based mitigation objectives are being met. This technical note presents a case study of the application of the *Western Kentucky Low-Gradient Riverine Guidebook* to monitoring the development of wetland functions on a number of bottomland hardwood forest sites in the first 15 years following restoration or abandonment from agriculture.

BACKGROUND: The HGM approach assesses the capacity of a wetland to perform specific functions. The approach has four integrated components (Smith et al. 1995). First, the HGM classification is used to categorize the wetlands in a region into groups of wetlands that are similar in hydrology, geomorphic setting, and the functions that are performed. Second, for a particular group or *regional subclass* of wetlands, reference wetlands are chosen that encompass the range of variability inherent in that subclass. Third, an assessment team of regional wetland experts identifies important variables affecting the level of performance of each function and develops an *assessment model* for each function. Variables are measurable attributes of the wetland itself and its landscape setting. Measures for each variable are converted to subindices scaled from 0 to 1. These subindices, in turn, are combined mathematically to calculate a functional capacity index (FCI) for each function, also on a scale of 0 to 1. Models are based on relevant literature and the team's experience and expertise, and are calibrated to local conditions based on data from reference wetlands. Finally, an *assessment protocol* guides the user in the level of data collection required to apply the models. All of this information is documented in a regional guidebook for assessing the functions of that regional wetland subclass.

The HGM approach has many potential applications in wetland regulation, planning, and management. It is designed primarily to assess the impacts of proposed projects on wetland functions, compare alternative project designs, and determine mitigation requirements. HGM assessment models can be used in wetland inventories to provide information on the relative functional capacities or quality of wetlands in an area, and can help guide management decisions aimed at increasing the functional output from disturbed or degraded wetlands.

This technical note presents a case study of the application of an HGM regional guidebook to the monitoring of wetland development in an area following restoration (replanting) or abandonment from agriculture (Coffey 1998). Monitoring of wetland mitigation projects is critical to Corps of Engineers regulatory responsibilities under Section 404 of the Clean Water Act. Section 404

permits that include wetland restoration or compensation as mitigation for unavoidable impacts often require monitoring of the developing wetland site to assure that mitigation objectives will be achieved. The typical monitoring program lasts 3 to 5 years and focuses on the early survival and development of wetland vegetation. In general, monitoring programs have not directly addressed the development of wetland functions in restored or constructed wetlands (Streever 1999).

CASE STUDY: Variables used in the regional guidebook for assessing the functions of low-gradient riverine wetlands in western Kentucky (Ainslie et al. 1998) were measured at 49 developing wetland sites in western Kentucky, western Tennessee, and eastern Arkansas. Although many of the sites were outside of the specified geographic limits (i.e., the reference domain) of the western Kentucky Guidebook, the climate, hydrology, soils, and dominant plants of low-gradient riverine wetlands were similar throughout the study area. Because the analysis required sites of known age since abandonment or restoration, it was necessary to look beyond the guidebook's stated reference domain to obtain an adequate sample.

Most of the sites had been converted to agriculture in the past and were now being allowed to revert to wetland vegetation. About half the sites had simply been abandoned and allowed to revegetate naturally. On the other half, natural revegetation was augmented with plantings consisting of ball-and-burlap tree seedlings. Site preparation was minimal, although some sites received minor grading to enhance ponding of floodwaters. The date of restoration or abandonment was known for each site and ranged from 1 to 15 years. Most sites in Kentucky and Tennessee had experienced some hydrologic modification. For example, drainage had been improved for agriculture in many fields and others were adjacent to channelized rivers. However, all study sites still experienced frequent overbank flooding.

Ten variables associated with the development of wetland vegetation were measured at each site (Table 1). Measurements were made in 0.04-ha circular plots following procedures given in the western Kentucky guidebook. Generally two plots were established at each site, with additional plots on heterogeneous sites.

Table 1. Variables measured at 49 low-gradient riverine sites in western Kentucky, western Tennessee, and eastern Arkansas*

Abbreviation	Variable	Measure
V_{TBA}	Tree biomass	Basal area of trees ≥ 10 cm DBH (m^2/ha)
V_{COMP}	Plant species composition	Percentage of dominant plant species that appear on a list of species found on reference standard sites
V_{SSD}	Understory vegetation biomass	Density of woody stems > 1 m tall and < 10 cm DBH (stems/ha)
V_{TDEN}	Tree density	Density of trees ≥ 10 cm DBH (stems/ha)
V_{GVC}	Ground vegetation biomass	Percent cover of herbaceous and woody vegetation < 1 m tall
V_{OHOR}	"O" horizon biomass	Percent cover of litter and organic material
V_{ROUGH}	Floodplain roughness	Estimate of Manning's roughness coefficient (*n*)
V_{SNAG}	Snag density	Density of snags ≥ 10 cm DBH (stems/ha)
V_{WD}	Woody debris biomass	Estimated volume of woody debris > 0.6 cm in diameter (m^3/ha)
V_{LOG}	Log biomass	Estimated volume of logs > 7.5 cm in diameter (m^3/ha)

*Abbreviations, names, and measures as given in Ainslie et al. (1998).

Other variables specified in the western Kentucky guidebook (e.g., floodplain slope, overbank flood frequency, soil clay content) are site characteristics that do not change appreciably over time. In a wetland restoration project, establishment of initial conditions for these variables involves either (a) selection of an appropriate site for the project, or (b) fixing the values of these variables through an appropriate engineering design (e.g., surface grading, soil amendments). However, this study focused on changes in the apparent functional capacity of restored wetlands due to growth and development of vegetation. Other site characteristics were assumed to be constant. One potential application of HGM assessment models is in selecting and preparing sites to improve the chance of success in wetland restoration.

Due to the small number of older sites available for study, sites were combined for analysis into the following age classes: 1-2, 3-4, 5-7, 8-10, and 11-15 years old. Generally, the most recently abandoned sites were dominated by herbaceous plants, first by annuals (e.g., tickseed [*Bidens frondosa*], barnyard grass [*Echinochloa crusgalli*], and smartweed [*Polygonum* spp.]) and then perennials (e.g., boneset [*Eupatorium perfoliatum*], slender rush [*Juncus tenuis*], and panicled aster [*Aster simplex*]). Woody species, such as red maple (*Acer rubrum*), sycamore (*Platanus occidentalis*), and sweetgum (*Liquidambar styraciflua*), were prevalent by year 5. By year 10, sites consisted primarily of dense young stands of trees and shrubs. Older sites typically had very little herbaceous cover due to shading by the dense shrub or tree canopy.

Statistics for each variable measured are summarized in Table 2. There were few significant differences between planted and naturally revegetating sites, and results were combined in Table 2. However, there were no planted sites in the 11- to 15-year age class; therefore, all data in that age class are for sites that were revegetating naturally.

Table 2. Field measurements of model variables (mean and range) from the Western Kentucky Low-Gradient Riverine Guidebook taken at 49 wetland sites in the early stages of development following abandonment or restoration

Variable (Units)	Stand Age in Years (Sample Size)				
	1-2 (n = 16)	**3-4 (n = 14)**	**5-7 (n = 8)**	**8-10 (n = 5)**	**11-15 (n = 6)**
V_{TBA} (m^2/ha)	0.00 (0-0)	0.00 (0.0)	0.31 (0-1.5)	16.62 (0-46.8)	3.46 (0-15.0)
V_{COMP} (%)	2.0 (0-7.5)	3.0 (0-7.5)	13.1 (2.0-26.0)	20.8 (14.0-41.3)	23.2 (13.0-67.5)
V_{SSD} (stems/ha)	369 (0-2,875)	2676 (0-22,875)	21,136 (1,050-29,250)	6,458 (925-23,688)	19,740 (6,875-35,125)
V_{TDEN} (stems/ha)	0.0 (0-0)	0.9 (0-12.5)	9.4 (0-50)	440.0 (0-850)	168.8 (0-750)
V_{GVC} (%)	85.0 (30.0-99.5)	68.0 (29.0-97.0)	39.7 (18.0-89.0)	48.7 (24.5-99.0)	25.2 (9.5-77.0)
V_{OHOR} (%)	7.0 (0-100.0)	10.0 (0-37.0)	38.0 (0-66.0)	46.8 (0-76.7)	56.3 (4.5-97.5)
V_{ROUGH} (Manning's n)	0.010 (0.01-0.05)	0.020 (0.01-0.06)	0.051 (0.01-0.07)	0.071 (0.05-0.10)	0.085 (0.03-0.12)
V_{SNAG} (stems/ha)	0 (0-0)	0 (0-0)	0 (0-0)	35 (0-125)	0 (0-0)
V_{WD} (m^3/ha)	0.0 (0-0)	0.5 (0-4.9)	16.5 (0-42.3)	21.4 (0-33.9)	6.5 (0-12.9)
V_{LOG} (m^3/ha)	0.0 (0-0)	0.0 (0-0)	1.8 (0-6.3)	13.0 (0-29.3)	0.0 (0-0)

There was considerable variability in the field measures for each variable even within an age class (Table 2). Much of this variability was probably due to site-specific differences in elevation, flooding frequency and duration, soil characteristics, sources of seeds and propagules, initial treatment (e.g., planted versus unplanted), wildlife use, and cultural alteration that could not be controlled. Several variables showed apparent trends over time. Average O-horizon biomass (V_{OHOR}), measured as percent cover of litter and decomposing organic matter, increased steadily with site age. So did site roughness (V_{ROUGH}), a reflection of the increased abundance and density of woody vegetation. Average values for V_{COMP}, the similarity in species composition between the assessed wetland and reference standard wetlands, were low in these early successional stands but increased through time. Herbaceous ground cover (V_{GVC}) generally declined as canopy cover of shrubs and trees increased. The average density (V_{TDEN}) and basal area (V_{TBA}) of trees increased during the first four age classes and dropped in the 11- to 15-year-old class. One reason for the decline may be that increased competition had resulted in stand thinning, temporarily reducing tree density and basal area in these stands. Average volumes of woody debris (V_{WD}) and logs (V_{LOG}) also increased initially and then dropped in the oldest age class. Abundance of debris may have been affected by import and export due to flooding events as well as production onsite.

CHANGES IN FUNCTIONAL CAPACITY: Four functions described in the western Kentucky guidebook were selected for this study because they depended heavily on the biotic variables measured at field sites. The functions were as follows:

- Cycle nutrients.
- Export organic carbon.
- Maintain characteristic plant community.
- Provide habitat for wildlife.

Subindices for each variable and FCIs for each function were calculated using the spreadsheet available on the Waterways Experiment Station Internet Web site (http://www.wes.army.mil/el/wetlands/datanal.html) for the western Kentucky guidebook.

Average subindices for each variable measured on the field sites are shown in Table 3. Subindices are scaled from 0 to 1, with 1 being equivalent to levels found on mature, fully functional (i.e., reference standard) wetlands. Subindices for most variables were low initially and increased with site age. In the 8- to 10-year age class, mean subindices ranged from 0.21 to 0.75, with most values between 0.50 and 0.70. Subindices for V_{COMP}, V_{GVC}, V_{OHOR}, and V_{ROUGH} continued to increase into the 11- to 15-year age class; however, subindices for V_{TBA}, V_{TDEN}, V_{SNAG}, V_{WD}, and V_{LOG} declined in the oldest class. The declining variables are all dependent upon the growth of trees, defined in the guidebook as woody stems >10 cm in diameter at breast height. Half of the sites in the 11- to 15-year age class (3 of 6) had not yet developed trees of this size. The lower subindices in the 11- to 15-year age class could have been due to the effects of a small sample size, the lack of planted sites in this age class, or to other factors (e.g., herbivory, human disturbance, lack of seed sources) that resulted in delayed forest establishment on these sites. For most variables, the ranges of subindex values within age classes were very wide (Table 3).

Changes in average FCIs through time are shown in Figure 1. A subindex of 1 was used in FCI calculations for all variables not actually measured on field sites (e.g., floodplain slope, soil clay content, etc.). Therefore, site conditions for these variables were assumed to be optimal. This assumption undoubtedly resulted in higher FCI values than expected for a typical field site. As indicated in Figure 1, all four functions considered here increased steadily from age class 1-2 through age class 8-10. All four dropped in age class 11-15, reflecting the limited number of trees on our sample of older sites.

DISCUSSION AND CONCLUSIONS: The HGM approach for assessing wetland functions was designed primarily to evaluate project impacts, compare alternatives, and estimate mitigation requirements for Section 404 permits. However, it can also be adapted for use in mitigation or restoration projects to monitor the development of wetland functions over time. Unfortunately, Section 404 permits that require wetland restoration as a permit condition often specify monitoring periods of 5 years or less (Streever 1999). For some functions, it may be possible to achieve a high level of performance, equivalent to reference standard conditions, over a short time period. For example, functions controlled by physical conditions on a site, such as its topography, soil conditions, or hydrologic regime, can often be restored quickly through proper engineering design. However, other functions, particularly those that depend upon the development of a mature plant community,

may require many years to achieve high levels of function. Even after 15 years, field measures of the biological variables in this study were still well below those found in reference standard wetlands. Consequently, FCIs for functions controlled by these variables were low.

Table 3. Subindices of model variables (mean and range) from the Western Kentucky Low-Gradient Riverine Guidebook taken at 49 wetland sites in the early stages of development following abandonment or restoration

	Stand Age in Years (Sample Size)				
Variable	1-2 (n = 16)	3-4 (n = 14)	5-7 (n = 8)	8-10 (n = 5)	11-15 (n = 6)
V_{TBA}	0.00 (0-0)	0.00 (0-0)	0.02 (0-0.08)	0.56 (0-1.00)	0.17 (0-0.75)
V_{COMP}	0.02 (0-0.08)	0.03 (0-0.08)	0.13 (0.02-0.26)	0.21 (0.14-0.41)	0.23 (0.13-0.68)
V_{SSD}	0.28 (0-0.95)	0.53 (0-1.00)	0.50 (0.50-0.50)	0.50 (0.50-0.50)	0.50 (0.50-0.50)
V_{TDEN}	0.00 (0-0)	0.00 (0-0.03)	0.02 (0-0.13)	0.60 (0-1.00)	0.28 (0-1.00)
V_{GVC}	0.27 (0.11-0.89)	0.46 (0.13-0.90)	0.78 (0.22-1.00)	0.68 (0.11-0.95)	0.88 (0.36-1.00)
V_{OHOR}	0.07 (0-1.00)	0.17 (0-0.61)	0.60 (0-1.00)	0.69 (0-1.00)	0.81 (0.07-1.00)
V_{ROUGH}	0.51 (0.50-0.64)	0.51 (0.50-0.66)	0.65 (0.50-0.75)	0.75 (0.64-0.96)	0.79 (0.50-1.00)
V_{SNAG}	0.00 (0-0)	0.00 (0-0)	0.00 (0-0)	0.22 (0-1.00)	0.00 (0-0)
V_{WD}	0.00 (0-0)	0.02 (0-0.25)	0.62 (0-1.00)	0.73 (0-1.00)	0.32 (0-0.65)
V_{LOG}	0.00 (0-0)	0.00 (0-0)	0.18 (0-0.63)	0.60 (0-1.00)	0.00 (0-0)

To use the HGM approach in monitoring restored wetlands, performance standards should reflect the normal growth and successional patterns that occur in a regional wetland subclass. Therefore, performance standards must be based on values of model variables and/or levels of function expected at a particular growth stage, rather than the levels at maturity. This is particularly important for wetland types that are slow to mature, such as forested systems. For example, it would be inappropriate to downgrade the performance of a recently restored wetland on an appropriate developmental trajectory simply because it lacked the large trees, woody debris, and species composition typical of mature systems. Thus, performance standards should change incrementally with site age.

The best way to establish these incremental standards is to track the biological and functional development of a sample of wetland sites from the time of restoration through maturity. Only then can one be sure that site development is on an appropriate track toward the desired mature and fully functional condition. An alternative approach, used in this study, is to sample a number of sites at different stages since restoration, under the assumption that differences between sites of various ages reflect the developmental trend of a single site through time. With this approach, however, one can't be sure that the different sites are actually following similar development tracks and will achieve the same end point on roughly the same schedule. In either case, there is increasing evidence in the restoration literature that the final mature condition of a restored plant community depends strongly on initial site conditions (e.g., soil characteristics, hydrology, initial treatments) and events occurring during development (e.g., fire, browsing by animals, human disturbance), all of which may vary from site to site. Therefore, establishment of performance standards for wetland restoration based

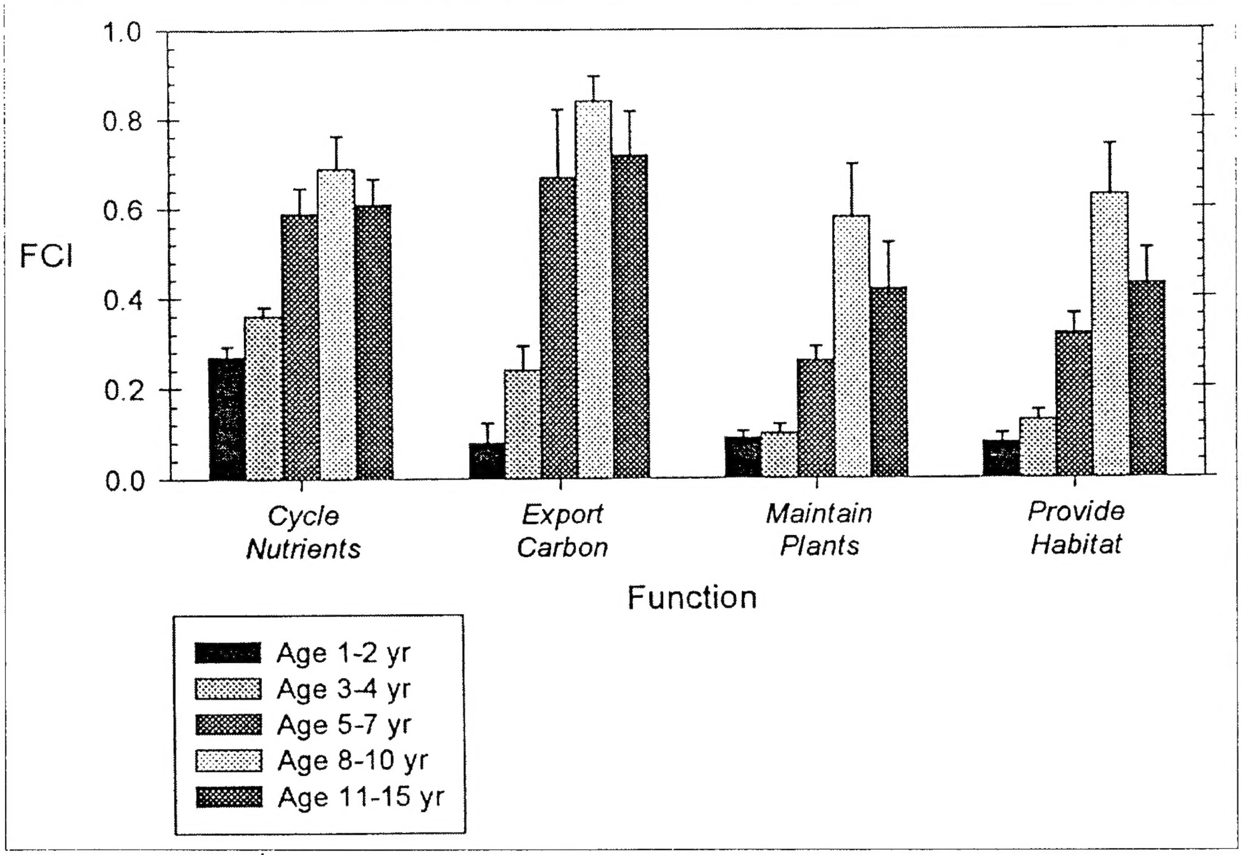

Figure 1. Average functional capacity index (FCI) values for four functions at 49 forested wetland sites of various ages since abandonment from agriculture or restoration by planting trees. Sites were grouped by age classes indicated in the legend. Error bars indicate 1 standard error of the mean.

on the HGM approach or any other method will always involve a measure of flexibility and professional judgment.

At the present time, few data exist that can be used to establish HGM-based performance standards for restoration of particular regional wetland subclasses. There is an immediate need to identify appropriate restoration projects and to establish the long-term monitoring programs that will provide the yardstick against which future restoration efforts can be judged.

POINT OF CONTACT FOR ADDITIONAL INFORMATION: For additional information, contact the author, Dr. James S. Wakeley, (601-634-3702, *wakelej@mail.wes.army.mil*). This technical note should be cited as follows:

> U.S. Army Engineer Waterways Experiment Station. (1999). "Case Study: Application of the HGM *Western Kentucky Low-Gradient Riverine Guidebook* to monitoring of wetland development," *WRP Technical Notes Collection* (TN WRP WG-EV-2.0). U.S. Army Engineer Research and Development Center, Vicksburg, MS. *www.wes.army.mil/el/wrp*

REFERENCES:

This technical note is based on data gathered by Patricia L. Coffey of the U. S. Army Engineer District, Nashville, as part of the requirements for a Master of Science degree in Biology from Tennessee Technological University under the supervision of Dr. Tom Roberts. Partial funding was provided by the Characterization and Restoration of Wetlands Research Program work unit "Application of the HGM Approach," directed by Dr. Mary Davis (WES). Dr. James Wakeley (WES) performed HGM analyses and wrote this note.

Ainslie, W. B., Smith, R. D., Pruitt, B. A., Roberts, T. H., Sparks, E. J., West, L., Godshalk, G. L., and Miller, M. V. (1998). "A regional guidebook for assessing the functions of low-gradient, riverine wetlands in western Kentucky," Technical Report WRP-DE-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Coffey, P. L. (1998). "Evaluation of early succession in bottomland hardwood forests," M.S. thesis, Tennessee Technological University, Cookeville, TN.

Smith, R. D., Ammann, A., Bartoldus, C., and Brinson, M. M. (1995). "An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices," Technical Report WRP-DE-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Streever, B. (1999). "Examples of performance standards for wetland creation and restoration in Section 404 permits and an approach to developing performance standards," Technical Note WG RS-3.3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.